ANNUAL BLOWFLY ATTRACTION AND COLONIZATION PATTERNS OF LIVER-BAITED TRAPS AND RABBIT CARCASSES IN SOUTHERN ENGLAND

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ABSTRACT

Despite numerous carrion decomposition and insect succession studies, fewer than ten have been published for the UK and none has been published in the past nine years that describes necrophagous insect communities. The aim of this research was to document the current colonisation and succession patterns in southern England, to aid distribution datasets and forensic investigations (estimation of time since death). Liver-baited traps and rabbit carcasses were placed outside monthly from April 2015 for a year. Weather data, observations and primary colonising calliphorid flies were collected daily, the latter using sticky traps placed near the rabbit and using a vial to catch flies on the rabbit itself. In summer, peak insect activity occurred within two days and decomposition was completed within 7–9 days. In January to March, this peak was extended to >11 days and the carcasses had not dried out within a month. *Calliphora vicina* Robineau-Desvoidy always dominated both carrion and liver-baited traps, however differences between species collected from traps and carcasses were observed. *Lucilia illustris* (Meigen) and *Lucilia caesar* (L.) were more often identified than *Lucilia sericata* (Meigen), particularly in spring, however only *L. sericata* oviposited on carcasses. The potential impact of changes in calliphorid diversity for forensic investigations using insect succession and development indicate the need for continued monitoring of local population dynamics, using suitable model carcasses, to ensure the existence of robust, current datasets.

INTRODUCTION

In the UK, entomology is considered a 'rare' evidence type, often bundled into ecological services, including other taphonomy-based factors such as palynology and soil analysis (Hall, Whitaker & Hart, 2015). This is despite its rapid development (Rivers & Dahlem, 2013). The ability of species of Calliphoridae to aid in determination of time since death using minimum post-mortem interval (minPMI) estimation is attributed to their rapid primary colonisation of and persistence on the corpse, which provides an essential protein source (Smith, 1986; Erzinclioglu, 1996: Davies & Harvey, 2012) for development of their larvae (Amendt *et al.*, 2011; Tomberlin *et al.*, 2012). Insect assemblage and individual age estimates can narrow down suspect and victim location and time, however minPMI estimation is only possible if current geographically relevant data are available (Amendt *et al.*, 2007), for example, suitable developmental data including locality specific lower developmental thresholds (VanLaerhoven, 2008).

As illustrated by Tomberlin *et al.* (2012), there is a notable lack of current distribution data in the UK and even more so in southern England. National Biodiversity Network Atlas maps (www.nbnatlas.org) are helpful, but with

individual species colonisation preferences, more detailed, forensically applicable data are required. Species common to the UK such as *Calliphora vicina* Robineau-Desvoidy and *Lucilia sericata* (Meigen) (Erzinclioglu, 1996) have been collected using whole cadavers (Chapman & Sankey, 1955; Lane, 1975; Blackith & Blackith, 1990; Isiche, Hillerton & Nowell, 1992; Smith & Wall, 1997b; Davies, 1999; Fisher, Wall & Ashworth, 2009) or traps (MacLeod & Donnelly, 1956; Hwang & Turner 2005, 2009). Other UK species such as *Protophormia terranovae* (Robineau-Desvoidy), *Phormia regina* (Meigen) and *Cynomya* spp. (Erzinclioglu, 1996) are now more often found in Europe (Grassberger & Frank, 2004), alongside the dominant *Calliphora* spp. and *Lucilia* spp. (Lefebvre & Gaudry, 2009; Iancu *et al*., 2015). Recent research in Europe has noted new temporal and carcass differences in assemblages, particularly in *Lucilia illustris* (Meigen), *L. sericata and Lucilia caesar* (L.) (Bourel *et al*., 1999; Matuszewski, Szafaowicz & Jarmusz 2013; Madra *et al*., 2015; Iancu *et al*., 2015). Therefore with accompanying indications that climate change is affecting local species distributions in Europe and America (Grassberger & Reiter, 2001; Grassberger, Friedrich & Reiter, 2003; Rosati & VanLaerhoven, 2007; Turchetto & Vanin, 2009; Vanin *et al*., 2011; Picard, 2013) it is imperative that insect assemblage and succession data are current and locality specific.

Calliphoridae can be collected using whole carcasses or meat-baited traps (Tomberlin *et al*., 2012; Farinha *et al*., 2014), the latter often conducted primarily due to ease and cost. Whilst the most commonly used alternative for human cadavers is the adult pig (*Sus scrofa*) (Whitaker, 2014; Matuszewski *et al*., 2019), other smaller carcasses such as deer, monkey, piglets, rabbits, rats and mice (Tomberlin *et al*., 2012) have also been used, despite unexplored differences in decomposition and insect colonisation (Simmons, Adlam & Moffatt, 2010; Brundage *et al*., 2011; Farinha *et al*., 2014; Sanford, 2017; Weidner *et al*., 2017). Standardisation of carcass and trap type is unlikely; however any affects must be acknowledged and caution taken when applying research data from a multitude of methodologies from different seasons and geographical locations.

The aim of this research was to examine and compare year-long, local Calliphoridae colonisation and succession of rabbit carcasses and liver-baited traps. The data indicate calliphorid species of importance for further developmental studies, which will enable quick, reliable and economical minPMI estimation.

Methods

Calliphoridae collection

Colonising calliphorids were collected using both liver-baited traps and European rabbit *Oryctolagus cuniculus* (L.) carcasses. The liver-baited trap (Fig. 1) was based on that used by Hwang & Turner (2005). It allowed one-way entry of insects to a chamber containing ~100g frozen-thawed pigs' liver, placed on paper towel to prevent insects drowning. The trap was protected from scavengers by placing it in a 13 mm metal mesh ('chicken wire') cylinder around a plant stem and pegged into the ground, allowing a partially concealed (from the public) partial sun/shade location.

The rabbits used were shot (single lethal wound), eviscerated and immediately frozen at −23°C for two weeks. Evisceration, which has been considered, was unavoidable given they were purchased as human food and no other sources were available. Freezing has been show to display no significant effects on decomposition, insect growth or insect colonisation (Day & Wallman, 2006; Stokes, Forbes & Tibbett, 2009; Bugajski, Seddon & Williams, 2011). Rabbit carcasses were thawed in

Fig. 1. The liver-baited trap used to collect adult Diptera. Liver is placed in the bottom on paper towel (a), insects are attracted in through funnels (b) and escape out through (c), becoming trapped in the top (d). Temperature was also indicated by the blue thermometer attached to the trap, although it was recorded hourly via a datalogger on the soil next to the trap (not shown).

a fridge (4°C) prior to placement in a secure dog crate, measuring 62 cm × 76 cm × 54 cm, with the base wrapped in 13 mm wire mesh ('chicken wire') to prevent scavenging.

The rabbit and liver-baited trap were placed ~15 m apart amongst shrubbery (partial-shade) in Ravelin Gardens (5047′30.2″N 105'47.5″W), at the University of Portsmouth. A thermochron iButton (www.maximintegrated.com) or an Easylog USB temperature and humidity data logger (www.corintech.com) was placed in the shade at each location, recording data hourly. Rainfall was obtained from Gosport Weather Station (www.gosportweather.co.uk), which is 4.5 miles west of Ravelin Gardens. Rentokil Advanced Fly Traps (www.rentokil.co.uk) were placed on the bottom of the crate next to the rabbit carcasses to aid collection of adult calliphorids, which were collected and replaced every one or two days.

Colonisation was monitored monthly, between April 2015 and April 2016, starting between first and third of each month. Rabbits were left to decompose until the skeletal remains stage or a maximum of one month, before disposal. Observations were conducted every day or two days, depending on decomposition progress. Decomposition stages were described as per Payne (1965). Adult calliphorids were collected from the carcass for approximately 5–10 minutes around noon, caught using a vial. A liver-baited trap was placed out at the same time as the rabbit, left out for 4–6 days and the adult calliphorids within it removed after this time.

Insect preservation, rearing and identification

Adult calliphorids were killed by direct submersion and preservation in 70% ethanol, or by freezing at −20°C prior to preservation and identification using morphological keys by K. Szpila (Gennard, 2012) and S. Ball (www.dipteristsforum.

org.uk/). *Lucilia* spp. were also identified using arista and ovipositor characteristics (Spence, 1954).

Decomposition rate calculation

Decomposition stages were described as per Payne (1965), with considerations for rabbit fur. To quantify the progression of decomposition and enable correlation of insect activity, accumulated degree-days (ADD) were calculated (Megyesi, Nawrocki & Haskell, 2005) using the average daily temperatures recorded from the datalogger located next to the rabbit and a base temperature of 0°C. The day of placement of the rabbits and traps was denoted day 1 and was between 08:00–19:00h.

RESULTS

Over 1000 calliphorid flies were collected throughout this year-long study, from liver-baited traps (748), rabbits and associated sticky traps (346), and reared from larvae collected from rabbits (141). Species, abundance thereof and decomposition rate were, as expected, strongly linked to the weather. Throughout the year (Fig. 2) mean temperatures ranged between 7°C (February) and 22°C (July) and humidity was between 62% (August) and 95% (November). No rainfall was observed during decomposition in July or October, in contrast to January when ~90 mm fell in the first 15 days.

Rabbit decomposition

The rabbit placed out in April 2015 was completely scavenged (carcass removed and the crate had moved location) within 24 hours and a lack of replacement cadavers prevented another being placed out directly afterwards. Additional 13 mm wire meshing cable-tied around the base of the crate prevented this in future. Decomposition rate of the carcasses (Fig. 3) was highly dependent on rainfall,

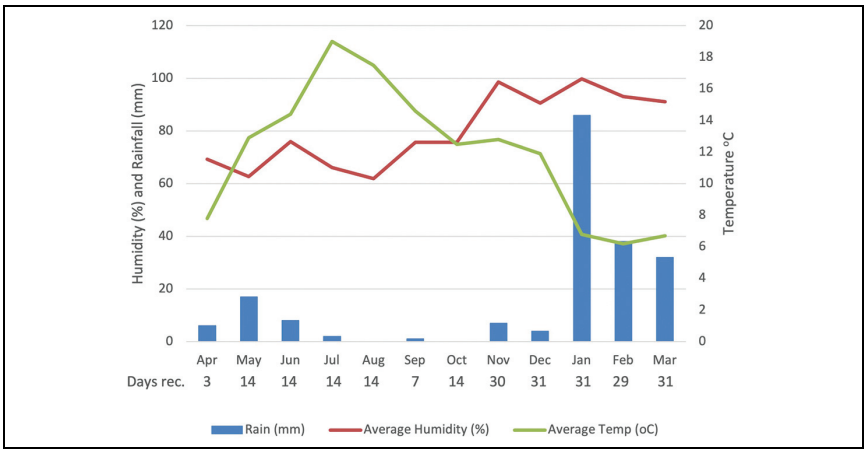

Fig. 2. Climate data for the decomposition site. The total monthly rainfall was estimated from a local weather station (Gosport weather). Average temperature and humidity were calculated from the rabbit data-logger data for the number of days from placement (day 1) stated under each month.

Fig. 3. Rabbit decomposition over a maximum of one month, with the month and day of decomposition indicated. a) Rabbits (eviscerated) were located in a dog crate under shrubs and monitored daily with a datalogger (white arrow) and a sticky trap (red arrow) – September Day 2. (b) & (c) show fur slippage, particularly when the rabbit was wet from rainfall – October Day 7. (d) shows active decay, with additional wounds (arrow) which attracted insect activity – September Day 4. (e) large abdominal maggot mass in the advanced decay stage – July Day 4. (f) significant tissue consumption leaves a leathery appearance – May Day 13. (g) indicates the dry stage, characterised by little tissue and mainly fur and bones – September Day 7. (h) shows the skeletal remains, all tissue consumed or washed into the soil below – August Day 31.

temperature and humidity, and correlated strongly with insect activity. Decomposition took 76–86 ADD to reach the active decay stage in spring and winter, which experienced increased rainfall, higher humidity and lower temperature compared to 44–50 ADD in summer and autumn (Table 1).

In summer, rabbits remained fresh for 1–2 days (Table 1) before insect colonisation (Fig. 3b & c) marking the active decay stage, was noted. In contrast in winter, when temperatures fell below 10°C and rainfall was above 20 mm, on average it took over nine days to reach the same stage. Eggs and larvae were noted in natural orifices and in the abdominal wounds at similar times (Fig. 3d – blue arrow). In summer, wasps (Vespidae) were also noted in wounds, chewing up balls of meat and ants were seen collecting small numbers of dipteran eggs from carcasses.

When daily temperatures reached above 15°C, larval masses broke through the abdomen within four days (advanced decay; Fig. 3e) and consumed all tissue (Fig. 3f) within a further 3–5 days, such that only fur and bones remained (Fig. 3g) and larvae were seen wandering in the soil, preparing for pupariation. At this point, daily monitoring and insect collection ceased and the start of the skeletal remains stage (Fig. 3h) occurred within the months between May and September. The colder, wetter weather in January–March markedly delayed active decay, with very little colonisation and tissue loss, up to 20 days post-mortem (Table 1).

Calliphoridae collected from rabbits

Adult calliphorid flies were collected using sticky traps and by hand using vials and presented as both absolute numbers and percentages of adults collected per month (Fig. 4). With the exception of November 2015, January 2016 and February 2016, adult Calliphoridae were observed throughout the year.

Adult *C. vicina* displayed monthly abundances from 7–100%, albeit in winter in numbers < 5 (Fig. 4) and was the primary visitor in May, October and March, with $> 50\%$ abundance (Fig 4b). *Calliphora vomitoria* (L.) displayed $< 5\%$ abundance in July and August, in contrast to December at 100% (7 specimens – Fig 4a). *Lucilia sericata* was collected from May through to October, reaching its peak in July (20 specimens, 44% abundance – Fig. 4), correlating with mean temperatures of > 12°C. *Lucilia caesar* and *L. illustris* were the only other species present, but some stuck to the traps were damaged and not able to be confidently distinguished from one another, and thus are denoted in this study as *Lucilia* spp. There were 133 of these undifferentiated adults over the course of the experiment; 50% of all *Lucilia* collected. In June, these two species (75%) outnumbered *L. sericata* (6%), but in July this had evened out to both 44% *L. sericata* and *Lucilia* spp. An increase in *L. caesar* and *L. illustris* was again observed from August to October (53%, 76% and 39.4%, respectively) when compared to *L. sericata,* which declined in abundance to 8% in September and 3% in October.

To provide early Diptera successional information, the days (1–10) on which species were collected was also recorded (Fig. 5). The warmest months of July and August (Fig. 2) showed the highest species diversity. In these months, as well as October, Calliphoridae were collected from day 2 of decomposition (day 1 being placement day). Collection of adults from carcasses in May, June and September occurred from day 3 (Fig 5), and after day 4 in December and day 15 in March. Between July and September, all adult activity had ceased by day 7, whereas this was extended to day 8 in June and October and day 10 in May (Fig. 5). *Calliphora vicina* was most abundant between days 2–5 every month and *C. vomitoria* occurred a little later, between days 3–5 in May, July and August (Fig. 5). *Lucilia sericata* was most commonly found after day 4, with few collected prior to this other than in July, when its peak occurred on day 3. *Lucilia caesar* and *L. illustris* were collected sporadically between days 2–7 for July–October, however only later on days 8 and 10 in June and May, respectively. In December and March, five *C. vomitoria* and seven *C. vicina*

Table 1. Rabbit decomposition rate, showing times to each stage observed in days and accumulated degree days (days multiplied by mean temperature). Stages described as per Payne (1965), '–' indicates the rabbit did not reach the stage in the month. '>' denotes the minimum number of days/ADD to reach the stage or within the season.

Stage	Active Decay	Adv. Decay	Dry	Active Decay	Adv. Decay	Dry
Month	Days To the beginning of each stage			Accumulated Degree Days (ADD) To the beginning of each stage		
Spring						
May–15	5	9	13	61.5	110.7	159.9
Summer						
Jun–15	4	7	11	54.0	94.5	148.5
Jul–15	2	4	8	43.6	87.2	174.4
Aug–15	2	4	9	35.2	70.4	158.4
Autumn						
Sep–15	2	4	7	30.0	60.0	105.0
Oct–15	4	8	20	55.6	111.2	278.0
Nov–15	5	10	18	64.0	128.0	250.2
Winter						
Dec–15	5	8	12	59.5	95.2	166.8
Jan–16	>12	–	–	91.2	–	–
Feb–16	11	20	–	75.9	75.9	–
Spring						
Mar–16	>15	>15	>15	111.0	>111	>111
Seasonal Means (n = 1–3)						
Spring	>10	>12	>14	>86	>111	>135
Summer	3	5	9	44	84	160
Autumn	4	7	15	50	100	211
Winter	9	>13	>15	76	>87	>111

were collected throughout the entire month; as decomposition remained incomplete within that time their appearance was not mapped.

Calliphoridae collected from liver-baited traps

The primary visitor to all traps, except in July, was *C. vicina* (n = 606; Fig. 6a), with an overall abundance of 71.0% (Fig. 6b). *Calliphora vicina* was the only calliphorid to frequent the trap in October, in contrast to August when it comprised 40.2% of the Calliphoridae and July when it was absent. *Calliphora vomitoria* was much less abundant at 10.6% overall however it was most numerous in August (Fig. 6a) with 22.8% abundance and then absent from September onwards. June and August were the only months in which all species were collected by traps.

The most abundant *Lucilia* spp. was *L. caesar* at 8.2% over the twelve months, despite it only being present from June to September. Its numbers peaked in

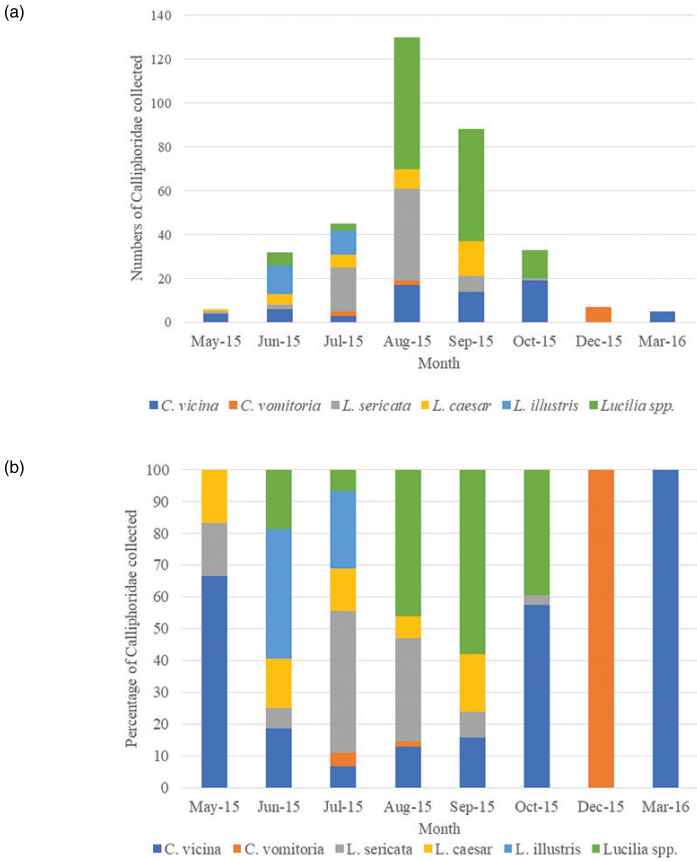

Fig. 4. Adult Calliphoridae collected from rabbit cadavers, by hand and using sticky traps, between April 2015 and March 2016. Data presented as the (a) number of Calliphoridae collected and (b) percentage of species of the total collected per month.

September (Fig. 6), with 41.5% abundance. *Lucilia illustris* and *L. sericata* displayed 5.1% and 2.1% overall abundance, respectively. Both species were present from May–September; one month earlier than *L. caesar*. *Lucilia illustris* peaked in numbers collected in July with 33% abundance and *L. sericata* peaked in August with 12% abundance (Fig. 6). The *Lucilia* spp specimens category were, as before, identified as being either *L. caesar* or *L. illustris* and totalled 12 specimens over the year, being present June–September.

Bait comparison

A comparison of the different species collected at the same time, from the rabbit and the liver-baited trap, was made over the year (Table 2). All species were found on

Fig. 5. Succession of adult Calliphoridae collected from rabbits, by hand and using sticky traps, from May to October 2015, from days 1–10 of decomposition. December and March are not shown due to minimal data. Data presented as the number of species collected per decomposition day.

rabbit cadavers, but *C. vicina* in July, *C. vomitoria* in December, *L. sericata* in July and October, *L. caesar* in May, and *L. caesar/illustris* (*Lucilia* spp.) in October were only collected from this source. Similarly, all species were found in traps, but *C. vicina* in February, *C. vomitoria* in May, June, February and March and *L. illustris* in May and August were only collected from this source. Over the eleven months (excluding April), *C. vomitoria* was collected from either the rabbit or trap in five months and only twice collected from both rabbit and trap in the same month.

Table 2. A comparison between Calliphoridae collected from rabbit cadavers (R), using sticky traps and manual collection, and liver-baited traps (T). Dates range from April 2015 to March 2016. Temperature is the monthly average for both locations (or trap only for April). '+' indicates presence of the species, '–' indicates absence.

Month	April	May		June		July		August		September		October		November		December		January		February		March	
Temp (°C)	10	12.3		13.5		21.8		17.6		15.0		13.9		12.8		11.9		6.8		6.2		6.7	
Site	T	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
C. vicina	+	+	+	+	+	–	+	+	+	+	+	+	+	–	–	–	–	–	–	–	+	–	+	+
C. vomitoria	+	+	–	+	–	+	+	+	+	–	–	–	–	–	–	–	+	–	–	+	–	+	+	+
L. sericata	–	+	+	+	+	–	+	+	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–
L. illustris	–	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
L. caesar	–	–	+	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
L. caes/ill	–	–	–	+	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–

Discussion

This study is the first in southern England to document calliphorid colonisation throughout a year, and although all species were collected by both methods, there were some potential differences to note, particularly *C. vomitoria* being collected more often with liver-baited traps than on rabbits.

Calliphoridae abundance and diversity

This study demonstrated *C. vicina* was the most abundant primary coloniser of shaded carcasses (Fig. 4), corroborating previous findings from the UK (Chapman & Sankey, 1955; Lane, 1975; Blackith & Blackith, 1990; Smith & Wall, 1997b; Davies, 1999) as well as in similar climates across Austria, France, Romania and Canada (Bourel *et al*., 1999; Grassberger & Frank, 2004; Lefebvre & Gaudry, 2009; Bygarski & LeBlanc, 2013; Iancu *et al*., 2015). The current study also indicated significant colonisation throughout decomposition, particularly in summer, by *Lucilia* spp., supporting previous research in the UK (Isiche, Hillerton & Nowell, 1992; Smith & Wall, 1997b; Hwang & Turner, 2005; Fisher, Wall & Ashworth, 2009).

As noted here, *L. sericata* occurred in warmer weather as early as May, with a peak in August and through to October on carcasses, which also supports previous data from spring/summer studies in the UK (Chapman & Sankey, 1955; Lane, 1975; Blackith & Blackith, 1990; Smith & Wall, 1997b), Romania (Iancu *et al*., 2015), Poland (Matuszewski, Szafaowicz, & Jarmusz, 2013; Madra *et al*., 2015), Austria

(Grassberger & Frank, 2004) and France (Bourel *et al*., 1999; Lefebvre & Gaudry, 2009). In contrast, published data from autumn/winter studies is limited so the current study provides an indication of the year-round calliphorid population in southern England.

Lucilia caesar and *L. illustris* are commonly observed in Southern Europe, across the Iberian Peninsula (Velasquez *et al*., 2010) and the presence and abundance of *L. caesar* and *L. illustris* on a carcass have been reported variably across the literature. The data presented here indicate *L. illustris* occurring earlier in summer, and *L. caesar* being present throughout summer and into autumn, in mostly greater abundances than *L. sericata*. This is similar to a more recent spring/summer study in the South West of England, that noted *Lucilia* spp. as early as April and with *L. caesar* in higher numbers than *L. sericata*, but they noted very few (< 10) *L. illustris* (Arias-Robledo, Stevens & Wall, 2019). Previous studies from the UK and Ireland, such as those by (Chapman & Sankey, 1955; Lane, 1975; Blackith & Blackith, 1990), show limited carcass/trap placement time intervals of up to two weeks in the summer, so a comparison cannot be made across the year. In Poland however, *L. illustris* was not reported at all by Matuszewski, Szafaowicz & Jarmusz (2013) then only seen on one of three carcasses in late summer alongside *L. caesar* (Madra *et al*., 2015).

Lucilia caesar and *L. illustris* occurred throughout days 1–10 of decomposition, in comparison to that found by (Lane, 1975), who found *L. caesar* on vole carcasses in the first 48 hours after death, followed by *L. sericata* in low numbers. Similarly, all three *Lucilia* species colonised mice and birds within the first four days of decomposition, but *L. sericata* numbers were lower, and colonisation across all carcasses was highly variable (Blackith & Blackith, 1990). Previously, *L. illustris* was not found in traps in Southern England (MacLeod & Donnelly, 1956). More recently, Hwang & Turner (2005) observed *L. caesar* and *L.illustris* in shaded traps, in lower numbers than *L. sericata*. The current study contrasts this and shows higher abundances of *L. caesar* and *L. illustris* than *L. sericata* in summer in both traps and on carcasses, which were in partial shade. Trap placement is known to affect the species collected, therefore placing traps in full sun would potentially attract more *L. sericata* than identified here, however the current study shows similar frequenting species to recent hedgerow traps between April and August (Arias-Robledo, Stevens & Wall, 2019). As seen by the observed migration of the oriental latrine fly *Chrysomya megacephala* (F.) to Indiana (Picard, 2013), potential temperature increases brought about by climate change could be facilitating the extended seasonality and distribution of these species, therefore theses data form a baseline for Calliphoridae presence across the year in Portsmouth, permitting future comparative studies.

From a forensic investigation perspective, these data affect the ability to estimate minPMI using predictable insect assemblages, succession and developmental timelines, as our existing UK-based data are different to the current study. Competition between Calliphoridae has been recorded throughout the colonisation and developmental process (Smith & Wall, 1997b; Rivers, Thompson & Brogan, 2011). In a competitive environment, including *L. illustris* and *L. silvarum* (Meigen), *L. sericata* did not appear to lay in significant numbers on cadavers, unlike *C. vicina*, despite high numbers of adults (Prinkkila & Hanksi,1995). This study briefly recorded larval development from *C. vicina* in May and June and *L. sericata* in June and July, with no larvae from *L. caesar* and *L. illustris* despite high numbers of adults of these species. Although this may be an artefact of small carcass size, as noted by (Lane, 1975) who used voles, the high numbers of adult *L. illustris* and

L. caesar may be changing our understanding of predictable insect succession, used for minPMI estimation. Although larvae from *L. illustris* and *L. caesar* are not yet recorded, new developmental data are required: there are numerous published datasets for *C. vicina* and *L. sericata* (Grassberger & Reiter, 2001; Donovan *et al.*, 2006) and a couple of developmental studies for *L. illustris* (Anderson, 2000; Wang *et al.*, 2016), but there are no published data for *L. caesar*. Herein lies a requirement to produce robust, comprehensive, geographically relevant developmental data for the Calliphoridae.

Comparative colonisation of carcasses and liver-baited traps

Brundage, Bros & Honda (2011) and Weidner *et al.* (2017) found that insects collected using fly traps generally corresponded with those found associated with human cadavers in California and pig carcasses in New Jersey, USA. In agreement with this, both liver-baited traps and rabbit carcasses yielded the same forensically relevant species throughout the year. *Calliphora vomitoria* was the most variable, being caught more in traps than on rabbits (Fig. 6), but multiple traps over multiple months years would be needed to assess a 'bait preference'. For the purpose of identifying which species are forensically relevant in the Portsmouth area, liver-baited traps are adequate, but succession data derived from traps (and small carcasses) should be used with caution to indicate human cadaver colonisation patterns (Dautartas *et al.*, 2018). Therefore, the data provide a baseline checklist of species frequenting small carcasses in Ravelin Gardens, Portsmouth, however further research utilising multiple carcasses and traps simultaneously, across multiple geographical locations is encouraged.

Limitations

Despite limitations including carcass type, pseudo-replication and limited time-scale, the preliminary data presented are valuable to guide forensic investigations. At the time, available space permitted the use of only one eviscerated rabbit and one liver-baited trap per month. The evisceration and carcass type will affect decomposition and succession, as a) eviscerated carcasses cannot go through bloat and b) larger carcasses may support different communities of insects (Hewadikaram & Goff, 1991; Davies, 1999). Smaller carcasses decompose faster (Matuszewski *et al.*, 2014), potentially altering species diversity and abundance, and differences in insect succession between animals such as mice and birds (Blackith & Blackith, 1990), and animals and humans have also been demonstrated (Dautartas *et al.*, 2018; Do *et al.*, 2019).

Comparative datasets exploring differences between carcass types, and multiple replicates thereof, are essential to understand variation. Adequate spacing is important to prevent pseudo-replication (Michaud, Schoenly & Moreau, 2012) and should two or more rabbits or traps have been used in the present study, it would have caused this problem. However, despite this limitation, the data presented still agree with that of Weidner *et al.* (2017), supporting the use of liver traps where carcasses are not available. A new study site has since been located for further work to test these comparisons with multiple replicates.

Finally, this preliminary dataset provides unique baseline year-round information for colonisers in the local area.

It has been reported that *Lucilia* ssp. numbers fluctuate year on year (Bourel *et al.*, 1999), supporting the need for studies of this type to occur continuously. The data in

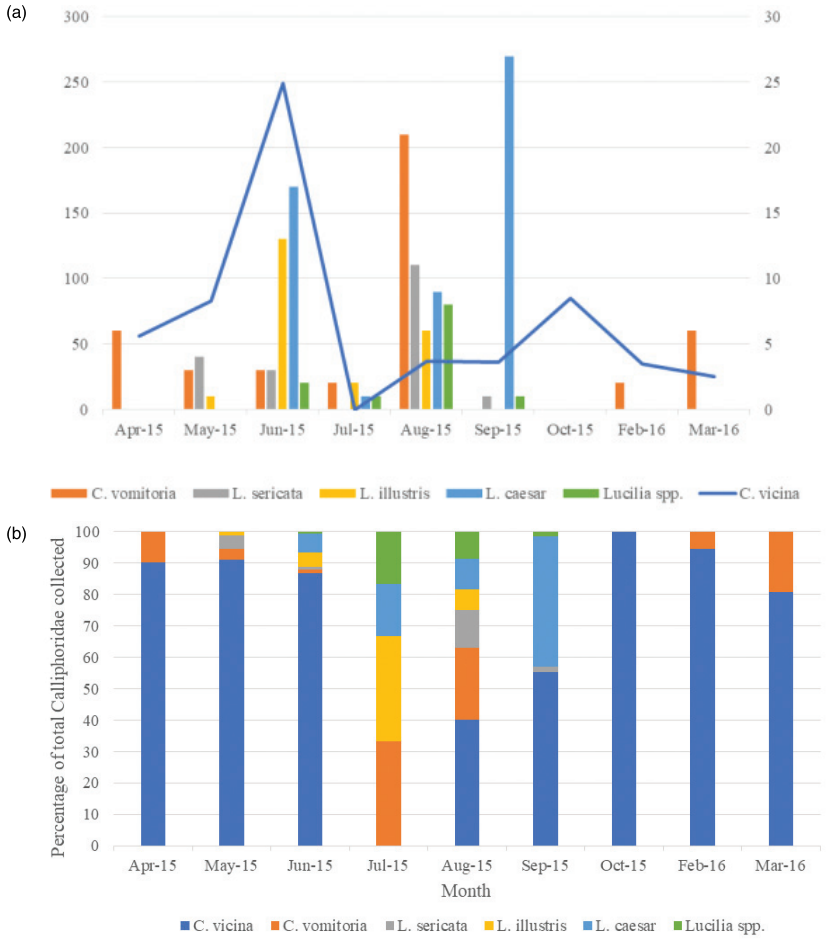

Fig. 6. All Calliphoridae adults collected from liver-baited traps between April 2015 and March 2016. Data presented as the a) number of Calliphoridae collected and b) percentage of species of the total collected per month.

this study supported many other European summer colonisation studies, adding to the geographical breadth of forensic entomology information but, as stated, extensive replication is necessary.

Conclusions

The calliphorid species identified here frequenting rabbit carcasses and liver-baited traps give local entomologists a valuable insight as to what may be present throughout the year. This enables a) specific developmental studies to be conducted, to calculate age of immature life stages collected from cadavers and b) an

understanding of local insect succession on cadavers, both facilitating a more accurate minPMI estimation which is valuable for local forensic investigations.

The main species colonising carrion in partially-shaded garden areas in Portsmouth are *C. vicina*, *C. vomitoria* and *L. caesar*. Expansion of this study using multiple traps, larger carcasses and comprehensive sampling over multiple years is required in order to obtain a modern representative dataset. This research also confirms the need to produce and publish detailed developmental data for a wider range of *Lucilia* spp. associated with cadavers in Portsmouth, to ensure that minPMI estimation remains possible and reliable using calliphorids.

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SHORT COMMUNICATION

Pollinator Interactions Database. – It is highly likely that members of this Society with lots of taxonomic and field expertise will be able to contribute to this new database. The Database of Pollinator Interactions (DoPI) documents British pollinator-plant associations. DoPI unites the disparate publications currently scattered throughout the scientific literature with unpublished reports and databases into a single online depository.

The importance of flower-insect interactions in maintaining global biodiversity, ecosystem resilience and agricultural output is well established. However, significant concerns remain about pollinator and plant population declines and shrinking distributions. For example, more than 40 British bee, wasp and butterfly species have become extinct in the last two centuries (Balfour *et al.*, 2018). While many potential causes have been identified, the long-term decline of flowers in our landscapes is considered a key factor (Ollerton *et al.,* 2014; Goulson *et al.*, 2015).

Despite the vital importance of pollinator-plant interactions, remarkably little is known about the flower preferences of many pollinator species, or which insects pollinate many flower species, and how these interactions change in space and time. To fill this gap the world's first online, open access, pollinator-plant interaction database has been created. It is hoped that DoPI will prove to be a useful tool and source of information for researchers and conservationists, and perhaps also farmers, horticulturalists, gardeners, and beekeepers.